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Evaluation of Thermal Viewers for Mine Detection

by
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Ahn Trang

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A brief field evaluation of four different infrared thermal viewers was conducted using buried and surface antitank mines as viewing objects. Under the conditions which existed, buried mines were visible for about half the viewing opportunities; surface mines were almost always visible. [Because of the very limited range of conditions of this brief evaluation, the results and conclusions presented here may not apply to other sets of circumstances and should not be considered "general."]

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Figures

Section I

Background

The impetus for this evaluation came from reports from recent military action in the Mideast (Desert Storm) in which land mines were sighted through tank infrared weapons sights.

Theoretical studies and experimental measurements of the effects of buried land mines on soil surface temperature distributions were done in the late 1950s and 1960s.[1] Evaluations of hand held thermal viewers for buried mine detection were done extensively in the early 1970s and reported in 1972[2] and 1976.[3] More recently, experimental airborne infrared mine detection systems have been demonstrated in 1990 and 1991. All of these efforts have confirmed that under favorable circumstances, mines and minefields can be detected by thermal imaging devices.

Section II

Introduction

OBJECTIVES

Two objectives existed for the work described in this report. The first was to evaluate available current thermal viewing devices with respect to their capabilities for tactical antitank mine detection. The second objective was to record a time-lapse video image of a typical buried mine over a complete diurnal cycle. The achievement of these objectives was limited by funding constraints to a single environment and a time span of a few days effort.

SCOPE

This report describes the results of a one week effort, including data collection for approximately three days which was performed at Fort A.P. Hill, VA, in November 1991. The target sample included approximately 25 antitank land mines of six varieties, principally U.S. Army types. These were emplaced as buried or surface devices according to their ordinary use. Three hand held thermal viewers and one larger weapon sight were used in the evaluation (Figures 1, 2, and 3). Characteristics of these viewing devices are shown in Table 1. Operational realism was subordinated to data collection in the conduct of the test. Locations of mines were known and viewed repeatedly to collect information including thermal measurements of the surface over the mines and over the surrounding areas.

Table 1. Viewing Devices

	AN/TAS-4	SRTS	MVX-48	HHV
Spectral Bandwidth (microns)	8-12	8-12	3-5	3-5
Field of View Used (Az x El) (degrees)	6.8 x 3.4	N/A	16 x 8	15 x 5
Mine. Res. Temp. Dif. (°C)	.10	N/A	.12	0.15

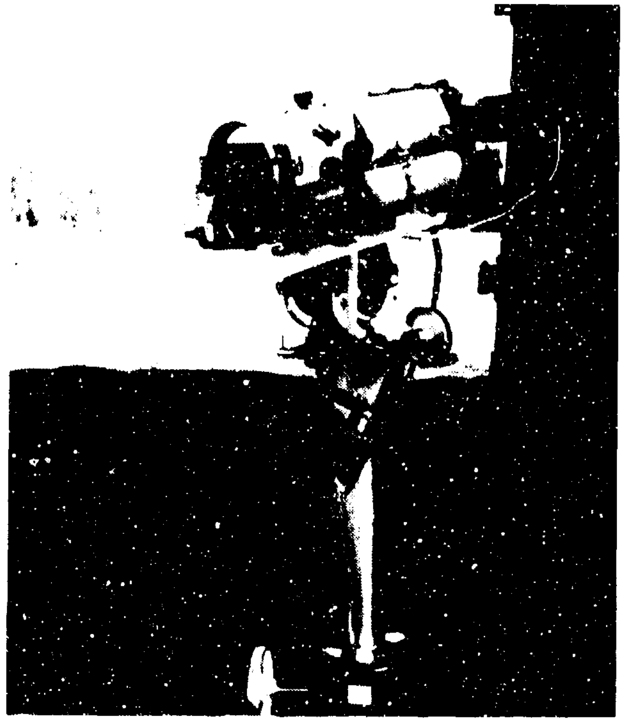

Figure 1. AN/TAS-4

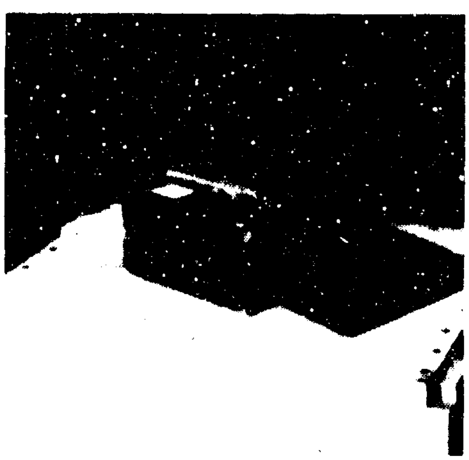

Figure 2. SRTS

Figure 3. MVX-48

Section III
Test Conditions

AREA

The test area selected was located near the Night Vision test facility at Fort A.P. Hill. The site provided a rudimentary roadbed, a grass-covered area, and an area which was mostly unvegetated, due to vehicular activity some time in the past. Figures 4 and 5 show these areas. The roadbed consisted simply of a layer of crushed bluestone bound by native clay and was not graded. The soil type in the area is mostly red clay mixed with gravel.

Figure 4. Test Area

Figure 5. Test Area

MINEFIELD INSTALLATION

The minefield was installed on 13 - 14 November. Sectors were laid out to incorporate a variety of mine types at various distances in each of the three environments. The soil was moist but not wet at the time of installation. Mines were installed by hand. Although a power auger was used to a depth of six inches for the installation of some of the mines, the holes were enlarged to finished size using hand tools. Spoil was deposited on the ground around the holes and scraped or shoveled back into place when the mines were deployed. In the three-day interval between installation and first viewing, the weather was cool and dry. When viewing began on 18 November, the moisture from any residual spoil seemed to have disappeared, although digging scars were still visible around the installed mines and for the most part remained somewhat visible during the week. The locations of mines buried in the grassy area were more readily visible to the unaided eye because of spoil residue on the grassy surface and discoloration of the grass itself.

Viewers were used from the back of a laboratory test van parked at a position which provided visibility to the aforementioned three minefield environments. Layout of the mines is shown in Figure 6.

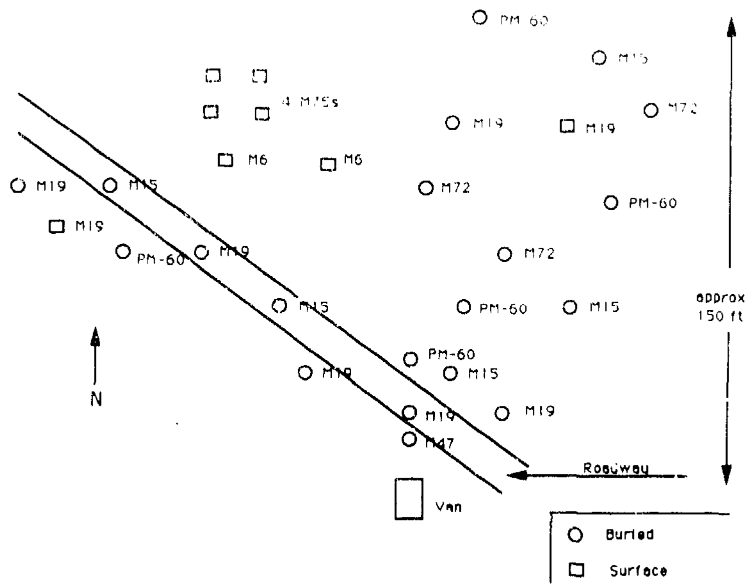

Figure 6. Mine Layout

TYPES OF MINES

The mines were inert common antitank mines which were wax filled to simulate the thermal properties of actual mines. Some characteristics of these mines are summarized in Table 2.

Table 2. Mine Characteristics

TYPE	SIZE (cm)	WEIGHT (kg)	CASE MATERIAL
M15	34 diameter 12.5 height	14.25	metal
M19	33 square 9.4 height	12.6	plastic
M6	28 diameter 7.6 height	7	metal
M75	12 diameter 6.6 height	1.7	metal cylinder, plastic ends
PM-60 (German)	31 diameter 13 height	10	plastic

VIEWING PROCEDURES

All recorded viewing was done from within or atop an instrument van, see Figure 7. The procedure used was to view the site of the mine from the van, reach a two or three person group consensus regarding its visibility, and then make thermal measurements at the mine site. The decision of visibility was not based on being able to discriminate the position of the mine from the clutter of the entire area of the minefield, but instead on being able to differentiate the position of the mine with respect to its immediate neighborhood. Thermal measurements used the hand held pyrometer first aimed directly at the location of the mine and second taking an average of a roughly 4-foot diameter circular path around the mine.

Hand held viewers were used in three ways: viewing from the instrument van, viewing from the bed of a pickup truck as it moved slowly along the road, and viewing on foot from various positions in the minefield.

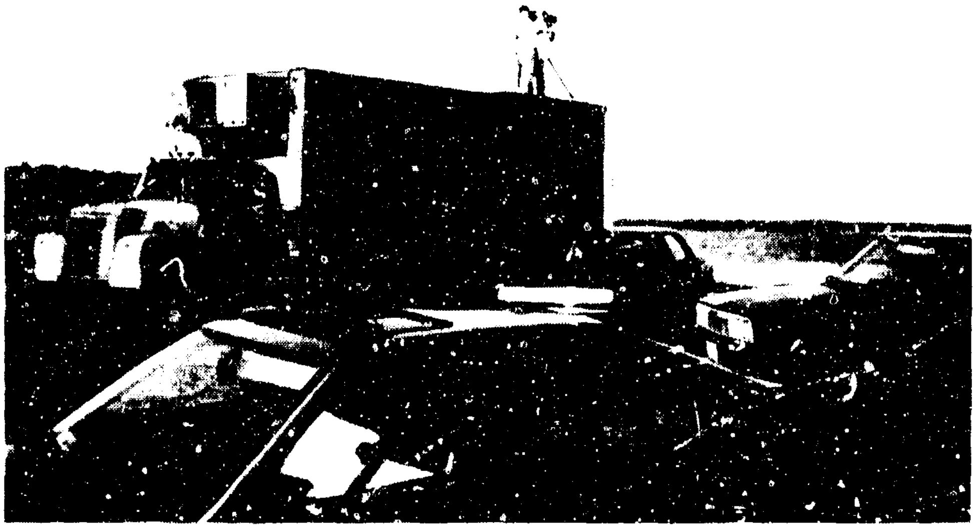

Figure 7. Viewing Procedures

Section IV
Results

DATA

Figure 8 is a histogram of temperature differences (over mine vs. near mine) in °C for all viewing opportunities. Figure 9 shows the mine visibility rate as a function of this temperature difference. The number of instances of delta temperatures above 2°C was too small to develop statistically stable data. Figure 10 shows visibility of buried mines (%), air temperature and soil temperature (°C) as functions of time from the beginning of the evaluation at 1000 hours on 18 November. During the days of data collection, no rain fell; wind speed never exceeded 4 knots and was mostly in the 0 to 2 knot range.

User comments regarding the hand held viewers are provided in the appendix.

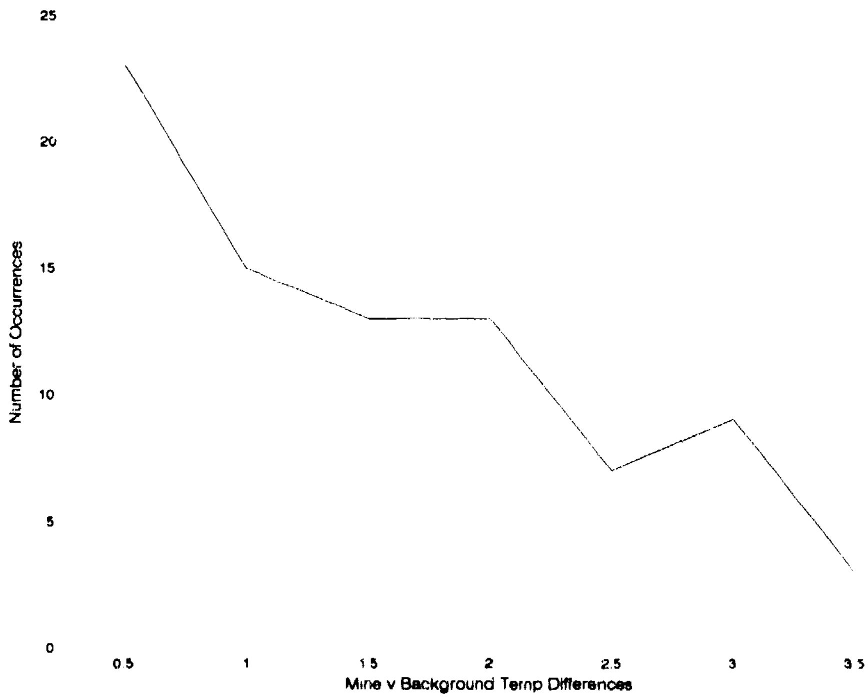

Figure 8. Histogram—Temperature Differences

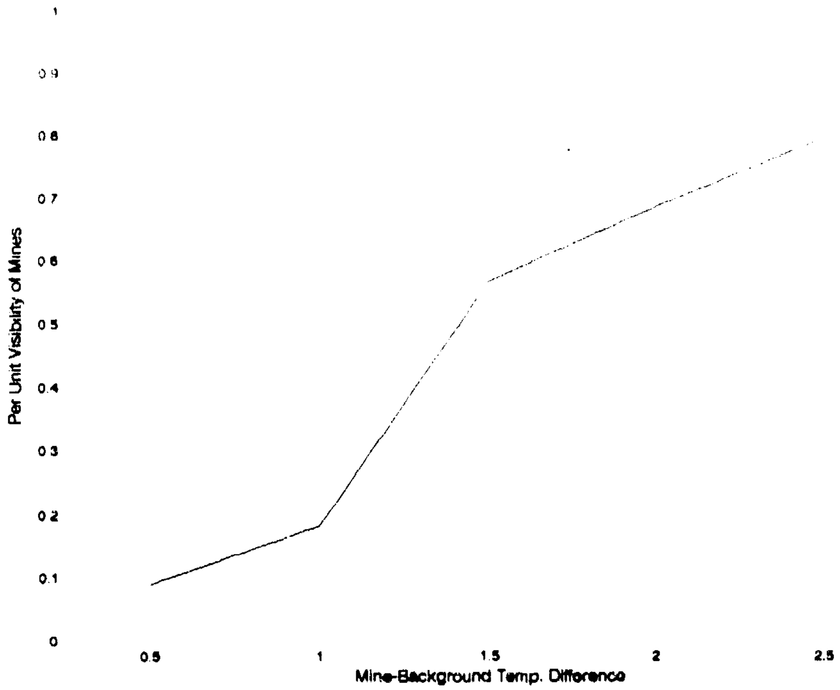

Figure 9. Histogram—Mine Visibility Rate

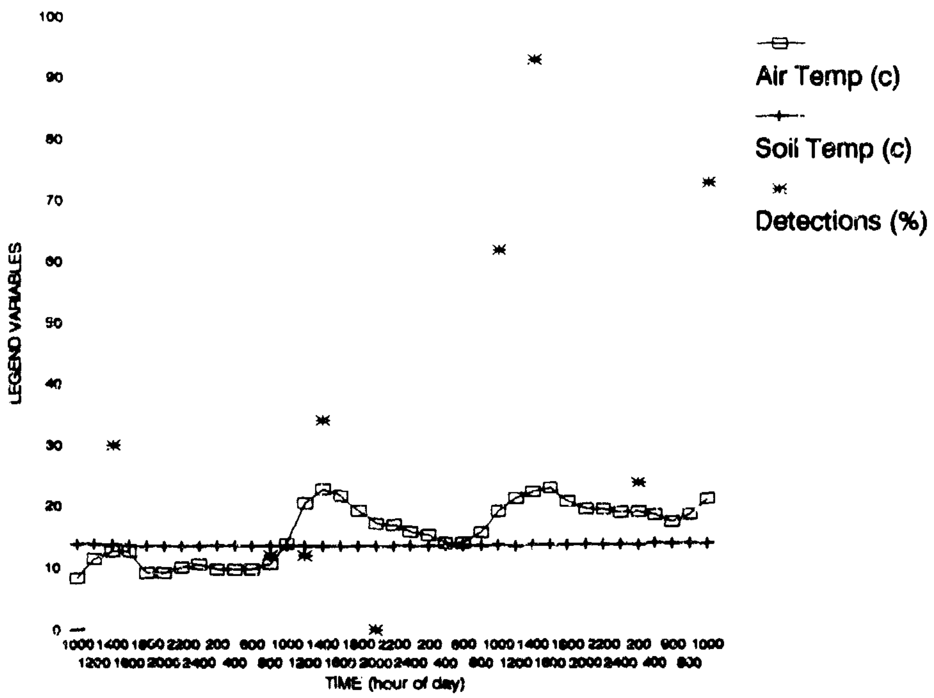

Figure 10. Histogram—Visibility and Temperatures

DISCUSSION OF RESULTS

Overall, the visibility rate using the AN/TAS-4 for buried mines was about 0.45 for all opportunities. For surface mines, the visibility rate was 0.98. The hand held viewers were used in comparison with the AN/TAS-4. The 8-12 micron hand held viewer performed comparably with the AN/TAS-4 against buried mines on the road, whereas with the 3-5 micron viewers, buried mines were not seen. Earlier reports have indicated that both near and far infrared are effective in viewing buried mines. All viewers were effective against surface mines.

The viewpoint from the van load bed was approximately 10 feet above ground, approximately the height of the AN/TAS-4 when vehicle mounted. The results of the first viewing session were affected by the contour of the test area which in one place was the backslope of a slight rise between the van and mine locations. The more distant mines were viewed at an angle which made them very difficult to see through the viewers.

All later data were recorded from atop the van at a height of 17 feet. This resulted in a better viewing angle and enabled data to be taken over a large enough area to include the variety of backgrounds available at the site. Since an operational viewing height would be approximately half that of the viewpoint on the van roof, one could expect that mine visibility in operational circumstances would be good to about half the distances noted here.

Up to about 200 feet in the circumstances of this minefield, the visibility of mines was determined by factors other than range. Beyond that range, mines became difficult to see because of distance.

The barren area of the test site was an unfavorable site for detection because the surface roughness due to past vehicle activities resulted in thermal background clutter which was comparable in magnitude to the buried mine signatures. The viewing method used compensated somewhat for this condition because much of the clutter could be ignored in the visibility decision. Detection in such clutter would otherwise have been very difficult.

The thermal images of buried mines seen throughout the days of data collection were, to a large extent, images of the burial scars. Throughout the week, no rain fell and, even though the surface moisture appeared to have equalized between the background surface and the surface over the mine location, the surface texture of the scars remained visible both to the thermal viewer aided eye and the unaided eye. Rain occurred during the weekend following the data collection. It was noted during the taping of the time-lapse imagery the following week that the thermal image much more closely matched the shape of the underlying mine than it had earlier. Further weathering in of the minefield prior to collecting data might have resulted in better detection results due to easier discrimination of mine shapes.

The effect of the season on the detection capability of the viewers was probably substantial. The angle of incidence of solar radiation in late November appeared to be 45 degrees or more from vertical at noon, and so the driving force which generates the detectable thermal differences would have been considerably smaller than during most of the rest of the year.

TIME-LAPSE VIDEO

Early in the week following the viewer evaluation effort, a time-lapse video recording was made of the image presented by the AN/TAS-4. The subject of the imagery was one of the M19 mines buried in the roadway a week and a half earlier. An additional M19 was positioned on the road surface to appear in the upper right corner of the recorded image as an item of reference. Recording was accomplished through a viewport in the instrumentation van's rear door; the camera was located about 25 feet laterally and 10 feet vertically from the mine. A controllable time-lapse video recorder was set to record continually to achieve a 12 minute record over the period of a 24 hour day. Recording began after noon on a clear, still, cool day. The image of the mine, which was warmer than background, was faint but visible. After thermal crossover around dark, the image, cooler than background, became quite clear by early evening and remained that way throughout the night. After sunrise, the sky was overcast and the image was not readily visible. This condition remained until afternoon when recording was terminated.

Section V

Conclusions

Thermal effects of mines and buried mines under favorable circumstances can be viewed by infrared imaging devices.

Separating valid images from background clutter in many environments is difficult. Roadbeds, because of their homogeneous nature, tend to be low clutter environments and should be a relatively favorable environment for detection of mines.

The spectral range of 8-12 microns provided visibility of buried mines which were not visible in the range of 3-5 microns under the circumstances of this evaluation.

The better view is the higher view, within limits. The overhead viewpoint of a low flying aircraft provides a less interruptible line of sight, a more distinctive plan view of an individual mine, and a greater likelihood of seeing patterns in conventionally deployed minefields.

Performance of thermal viewers in detection of mines is highly dependent on conditions, as can be seen from the varying results obtained at one site over a very brief time. The data and conclusions provided in this report should not be considered definitive in applying such devices under different conditions of soil, ground cover, soil moisture, insolation, cloud cover, wind, precipitation, and other factors.

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Appendix

Individual Observer Impressions of Viewers

INDIVIDUAL 1

1. **Effectiveness in viewing buried mines.**

   AN/TAS-4: Good and best among others. Although shapes of mines were rarely seen, the disturbed soil above mines was clearly identified.

   SRTS: Mines were never identified, but view was great.

   MVX-48: Mines were never identified, resolution was kind of poor.

   HHV: View was great with better resolution than other portables. Only disturbed soil could sometimes be identified.

2. **Effectiveness in viewing surface mines.**

   AN/TAS-4: Very good shapes, contours, and other features were often seen.

   SRTS: Good

   MVX-48: Target seen but not easily identified.

   HHV: Targets could sometimes be seen.

3. **General image quality and practicality of use.**

   AN/TAS-4: Best image quality; confidence in identifying targets.

   SRTS: Good quality image. Everything in one piece.

   MVX-48: Not very heavy. Not very good resolution.

   HHV: Heavy. Hard to use forehead ON switch. Difficult to carry with two heavy pieces. Resolution OK. Targets not often seen.

INDIVIDUAL 2

1. **Effectiveness in viewing buried mines.**

   AN/TAS-4: Excellent compared with other viewers. Could see some buried mines at long distance.

   SRTS: Good, could see some buried mines at short distance.

   MVX-48: Could not see buried mines.

   HHV: Could not see buried mines.

2. **Effectiveness in viewing surface mines.**

   AN/TAS-4: Excellent, could see all surface mines with high image quality.

   SRTS: Good, could see all surface mines.

   MVX-48: Good, could see all surface mines.

   HHV: Good, could see all surface mines.

3. **General image quality and practicality of use.**

   AN/TAS-4: Excellent long range viewer for use on combat vehicles. Not usable hand held.

   SRTS: Excellent for hand held use due to light weight, small size and simple operation.

   MVX-48: Acceptable for hand held use.

   HHV: Good for hand held or vehicle-mounted use. Better image quality than other hand held viewers.

INDIVIDUAL 3

1. **Effectiveness in viewing buried mines.**

   AN/TAS-4: Able to detect mines buried in road and a few in dirt with patches of grass and weeds. Use of external monitor was helpful because of red phosphor used in the viewer display. Off-road mines were difficult to identify due to clutter.

   SRTS: Able to detect mines buried in the road and a few were visible off-road. Off-road mines were difficult to identify due to clutter.

MVX-48: Similar to SRTS.

HHV: Similar to SRTS.

2. **Effectiveness in viewing surface mines.**

AN/TAS-4: All the mines on the surface were detected at the hours we tested. Mines were visible at up to approximately 300 feet.

SRTS: All surface mines were detected at the hours we tested. Surface mines were visible at up to 50 feet.

MVX-48: All surface mines were detected at the hours we tested. Mines were visible at up to 300 feet when the sight was adjusted correctly.

HHV: All surface mines were detected at the hours we tested. Mines were visible at up to 300 feet when the sight was correctly adjusted.

3. **General image quality and practicality of use.**

AN/TAS-4: The external monitor provided easy viewing of mines. Contrast and gain adjustments were helpful in detecting buried and surface mines. Uses bottled gas for cooling. Not being hand held, this unit was easy to use without operator fatigue.

SRTS: Lighter and easier to operate than the other thermal viewers. Operator fatigue and a need for extra batteries would limit viewing time.

MVX-48: Heavier than SRTS. Operator fatigue and need for extra batteries would limit viewing time with this device.

HHV: The device is not practical for hand held mine detection. Its forehead pressure power ON switch is uncomfortable and fatiguing to use. This unit consisted of two modules, viewer and support modules, connected by a heavy cable. A cooling gas bottle and battery connected to the support module. This arrangement was not as convenient to use as the other two self-contained single unit designs. The unit tested suffered intermittent operation when the connecting cable was moved.

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